NIPER-384
Distribution Category UC-122
September 1988

Status Report

EVALUATION OF PETROLEUM TECHNOLOGY AND ITS ENVIRONMENTAL IMPACTS

Project BE15, Milestone 2, FY88

By M. E. Crocker and M. P. Madden

Work Performed for the
U.S. Department of Energy
Under Cooperative Agreement
DE-FC22-83FE60149

E. B. Nuckols, Project Manager
Bartlesville Project Office
U.S. Department of Energy

DISCLAIMER

IIT Research Institute
NATIONAL INSTITUTE FOR PETROLEUM AND ENERGY RESEARCH
P. O. Box 2128
Bartlesville, Oklahoma 74005
(918) 336-2400

TABLE OF CONTENTS

TABLES

ILLUSTRATIONS

EVALUATION OF PETROLEUM TECHNOLOGY AND ITS ENVIRONMENTAL IMPACTS

By M. E. Crocker and M. P. Madden

ABSTRACT

One of the most notable studies regarding enhanced oil recovery (EOR) is the National Petroleum Council's 1984 report on EOR. However, many changes have occurred in the oil and gas industry in the past four years. The objective of this report is to update the impact of environmental constraints on the implementation of EOR technology. It was found that progress in this area has been insignificant since 1984. One of the major reasons for the lack of progress has been the soft price of oil which has forced the industry to look closely at potential production before beginning any EOR process. The most important piece of legislation to be acted upon during this time , which could have had a tremendous impact on the oil industry, was the EPA decision not to regulate drilling mud and produced waters as hazardous wastes.

INTRODUCTION

Since 1986, interest in enhanced oil recovery (EOR) has decreased because of the soft price of oil (Fig. 1).[1] Oil prices have forced producers to look closely at potential production before beginning an EOR process. Even so, secondary and tertiary production processes are, in many cases, less of an economic risk than exploration because the potential for profit is more predictable. Production from CO_2 floods has increased by 125% since 1986.[2] This increase can be attributed to the completion of several CO_2 pipelines into heavily produced areas and to advances in CO_2 recycling equipment, making CO_2 injection a more economical option.

Among numerous studies about EOR and the environment, one of the most notable is the National Petroleum Council's 1984 report on Enhanced Oil Recovery.[3] Changes in the oil industry and EPA regulations since its publication make the NPC report somewhat dated, but according to that report, major environmental impacts associated with EOR include:[3]

- possible contamination of agricultural land,
- use of potable water for EOR operations,
- possible contamination of surface and ground water,
- possible contamination of air quality,
- depletion of area water resources, and
- extended land use.

With any EOR process, the effects of damage to the land are greater than those from conventional methods because of the extra equipment involved and the use of the land for a longer period of time. The risk of air pollution is magnified through emissions from generators and pumps. Some EOR processes can produce concentrations of H_2S, a highly toxic gas, increasing the risk of exposure to personnel and area wildlife. Soil contamination through spillage is always a problem at a well site. Necessary pressure increases in the reservoir can cause the formation to fracture and allow leakage of reservoir fluids to the surface or into neighboring water resources. Fresh water is a finite resource. Depending on the method, some EOR processes require as much as 10 bbl of fresh water for every barrel of oil produced. In areas of heavy development, this demand for fresh water causes a rapid drain on local supplies.

Landscape scars and air and soil pollution are visible concerns of expanding oil exploration, but water depletion and contamination can go unnoticed for many years because they are often unseen and difficult to pinpoint.

The NPC report[3] addressed many of these impacts, but the study also noted several areas of environmental impact not addressed adequately in current field practices at the time the report was written. Specific items delineated by the NPC study for each EOR process include:

CHEMICAL PROCESSES

Potential Environmental Impacts

- Exposure to toxic materials
- Protection of fresh groundwater resources
- Protection of surface water
- Competition for fresh water supplies

Potential Environmental Impacts Not Adequately Addressed

- Additional research into toxicity of EOR chemicals
- Define the potential damage of surface water due to surface disposal
- Use of chemicals that will tolerate higher salinity water-reducing the demand for fresh water

MISCIBLE PROCESSES

Potential Environmental Impacts

- Groundwater resources
- Surface waters
- Land use
- Air quality

Potential Environmental Impacts not Adequately Addressed

- Potential environmental impacts from miscible displacement were noted to be relatively minor
- Spills and/or leaks

THERMAL PROCESSES

Potential Environmental Impacts

- Air quality
- Land use
- Heat/sound emissions
- Occupational safety and health
- Water supply
- Water quality
- Solid waste
- Toxicity

Potential Environmental Impacts Not Adequately Addressed

- Discharge of produced water to surface, contaminating fresh water with either brine or chemicals

The Resource Conservation and Recovery Act (RCRA) has until recently been the major policy regulation affecting EOR wastes. Amendments to the RCRA in 1980 directed the Environmental Protection Agency (EPA) to present to Congress a report on the potential damage to the United States drinking water supplies from current petroleum industry practices.

This project further defines the areas noted in the NPC report as needing additional research. The impact of current environmental regulations on the implementation of EOR technology is also discussed.

CURRENT EOR ACTIVITY AND ASSESSMENT

To justify the assessment of specific EOR processes on the environment, a summary of the emphasis of current EOR activity is presented. The trend for new EOR starts is that of a steady decline since 1981[1] which corresponds to an equivalent decline for the price of oil for that period.

Recent developments in the Middle East preclude any predictions as to the price of oil in the near term. However, projections by oil companies estimate that near term oil prices will be lower than prices projected earlier. Naturally, EOR will react accordingly with smaller numbers of projects being proposed and/or started. A listing of current activity for each specific type of EOR process is presented in table 1,[1] which shows that EOR activity has reacted severely to recent changes in oil prices, with 99 starts in 1984 dropping to 13 starts in 1987.

This dramatic decrease in EOR activity is perhaps the major reason for difficulties noted in attempting to find data relevant to this report. Other uncertainties have included the possibility of EPA intervention in regulation of oilfield wastes. New regulations as imposed by state and federal agencies also have been dramatic, as shown in figure 2.

EOR POTENTIAL

The United States is currently importing more than 40% of the oil used in this country. Lower crude oil prices has had a negative impact on exploration and the start-up of new EOR projects. EOR processes can add from 7.4 to 34 billion bbl of oil to the current U.S. proven reserves.[5] Projected recoveries for specific EOR processes are presented in figure 3.[5] EOR can be an expensive, financially front-loaded, high-risk type of project. A large immediate investment is sometimes required to initiate a project that could produce slow returns over a long period of time.[5] The unpredictability and large up-front expenses have restrained the oil industry from more extensive applications.

EOR RELATIONSHIP

There are three major EOR recovery processes:

1) Chemical
2) Miscible

3) Thermal

The relationships among the three methods are shown in figure 4.[5] Each EOR process has the potential for specific types of environmental impact. Some of these potential environmental impacts can be seen immediately, but most deleterious effects are gradual and may not be noticed for years.

ACKNOWLEDGMENTS

The authors acknowledge the financial support of the U.S. Department of Energy, Bartlesville Project Office, for this project.

POTENTIAL ENVIRONMENTAL IMPACTS DUE TO EOR

The following discussion on environmental impacts which result from EOR processes will focus on an update of those specific areas as noted in the NPC study.[3]

The following areas were designated by the NPC[3] as potential environmental impacts not adequately addressed:

- CHEMICAL
  (1) Research into toxicity of EOR chemicals
  (2) Disposal of produced water and its effects
- MISCIBLE
  1) Spills/ leaks of solvents
- THERMAL
  1) Discharge of produced water to the surface contaminating fresh water with either brine or chemicals

Some of these impacts are specific to an EOR process. However, most are intricately related and, in such cases will be reviewed as an overall impact rather than process specific. Improvements in technology, techniques, and identification of new potential impacts will be discussed. Although this discussion will cover a number of scenarios, this is not intended to imply that any major environmental problem will necessarily occur. The oil industry has a good record as far as environmental considerations are concerned. Since the EOR processes discussed are secondary and tertiary processes. Many of the mechanisms and methods used for EOR have been evaluated. Regulations as defined by state and federal legislation are also in place for minimizing and controlling potential environmental problems.

UPDATE OF POTENTIAL ENVIRONMENTAL CONSTRAINTS

Chemical EOR processes are, of course, where most environmental impacts would occur from the use of chemicals to enhance oil recovery. Thermal processes do employ chemicals, polymers, and other mobility-control agents as aids in oil recovery; miscible recovery processes; however, use few chemicals. Perhaps the major concern involving toxicity is the case of chemicals entering ground or surface waters. This would present a worst case scenario. Other potential impacts could arise from spills, leaks, or other similar accidental exposures. Potential contamination of surface or ground water can occur by several different ways. A number of potential ways are depicted in figure 5, which illustrates worst case scenarios for contamination of ground or fresh water.

A background paper[6] was prepared for the EPA to aid EPA headquarters in the Mid-Course Correction (MCC) effort to determine if the Underground Injection Control (UIC) program, as it is currently being implemented, is effective and adequate to ensure the protection of all underground sources of drinking water (USDW).

The following recommendations were made to ensure that fluids injected into commercial wells are adequately contained:[6]

(1) It is recommended that review of all UIC permits for commercial brine disposal wells be mandatory in order to ensure that adequate fluid

compatibility analyses and/or corrosion control measures are being implemented by the operator.

(2) More frequent injection parameter monitoring requirements are recommended. It is recommended that recording be required daily and that reporting be required monthly.

(3) Facility security measures (i.e. locked gates, fenced facilities, and/or 24-hour guard) are recommended.

(4) Verification of the manifests by the UIC regulatory agency should be mandatory. This verification should entail a complete accountability of injected fluids.

A recent study[7] was conducted for the American Petroleum Institute. The results of the study indicate that the risk of water from oil and gas industry injection wells reaching an underground source of drinking water (USDW) is small in the United States.

This report was useful in providing additional data to support the EPA's recent report to Congress that concluded that the underground injection of produced water should not be regulated as a hazardous waste.[7]

The determination[7] was made by:

- Identifying areas of the U.S. where the potential exists for corrosion selected failures allowing release of injection water in a USDW.
- Developing maximum quantifiable limits for potential USDW contamination frequency in those areas.

The U.S. oil and gas industry operates 166,000 water-injection wells which inject 60 million bbl/d of water into subsurface formations into 39 producing geologic basins.[7] Only 20 of these basins are rated as having a minor potential for external casing corrosion. These 20 basins contain 52% of the water-injection wells and inject 35% of the water in the United States. The other 19 producing basins are categorized as having either a possible or significant potential for external casing corrosion. These wells account for 65% of the injected water in the United States.

Collins and Madden[4] made a number of conclusions and recommendations regarding disposal of EOR and waste fluids. They concluded that additional information and knowledge are needed concerning compatibilities and precipitation reactions relevant to injected EOR fluids, waste fluids, and even reinjected formation brines.[4] They also concluded that for spills caused by accident and/or incompetent storage tanks, mixing tanks, trucks, or injection systems (including the well) that there generally is no standard technology available to instigate the following:

(1) cleaning operations or
(2) monitor the spill
(3) contain the spill and
(4) perform remedial actions to restore the quality of the air, land and/or water.

Specific recommendations made as a result of this study[4] include:

(1) Better methods of proving the integrity of injection wells, production wells, storage tanks, and treating facilities should be devised and proven.
(2) Safe methods should be developed and used to prove that injected solutions are not entering geologic zones other than those for which the EOR operation was designed.
(3) Research should be conducted to develop standard procedures to provide remedial action in the event of a spill that contaminates land, water, or air.

A recent paper on the evolution of the carbon dioxide flood processes[8] indicated that carbon dioxide flooding has become one of the major EOR processes in the United States. This study noted that CO_2 is a noncombustible, nonpoisonous gas which tends to exclude air in topographically low areas making it a safety hazard. Poisonous hydrogen sulfide as a contaminant was noted to be a particular safety hazard. Both of these issues were noted to be less critical to the design of a CO_2 flood, but of major concern to the field operator.

Perhaps the biggest newsmaker in the area of waste disposal has been the possibility of EPA classifying oilfield wastes as hazardous. Much to the relief of the petroleum industry, the EPA has decided not to regulate drilling mud and produced water as hazardous waste.[9-10] In a report to Congress, the EPA said present state and federal legislation appears to be adequate and sweeping federal legislation is unnecessary and impractical.[9]

EPA's report did say that there are some gaps in state and federal regulations governing disposal of mud and brine and enforcement is inadequate in some states. For example, some states have insufficient control on landfarming, roadspreading, pit construction, and surface water discharge practices. So the EPA said it will develop regulations to improve protection under RCRA, the Clean Water Act, and the Safe Water Drinking Act and will work with states to encourage changes in their rules and enforcement.[9]

CONCLUSIONS

Additional progress in the area of the impact of environmental constraints on the implementation of EOR technology has been insignificant since 1984. The major reason for this lack of advancement is economics. The soft price for oil has forced producers to look closely at potential production before beginning any EOR process.

The most significant legislation regarding oilfield wastes has been that the EPA has decided not to regulate drilling mud and produced water as hazardous wastes. If produced waters had been considered hazardous, a new set of rules and regulations would have imposed additional hardships on the producer. New regulations as imposed by states and federal agencies have already been dramatic.

Separate studies have been made by the EPA and the American Petroleum Institute regarding disposal of water from oil and gas wells. Both studies noted areas that could be improved in the disposal of wastes from oil and gas wells; however, the majority of these recommendations are presently being applied. These reports were also very useful to the EPA regarding their decision not to regulate drilling muds and produced waters.

REFERENCES

1. Thomas, R. D., J. F. Pautz, and M. P. Madden. Applications of EOR Technology in Field Projects. Dept. of Energy Report No. NIPER-366, Sept. 1988.

2. Aalund, L. R. EOR Projects Decline, But CO_2 Pushes Up Production. Oil and Gas J. v. 86, No. 16. April 18, 1988, pp. 33-73.

3. National Petroleum Council, Enhanced Oil Recovery, June 1984, 96 p.

4. Collins, A. G., and M. P. Madden. Disposal of EOR and Waste Fluids. Depart. of Energy Report No. NIPER-136, June 1986.

5. Goodlett, Gilbert O., M. M. Honarpour, H. B. Carroll, and P. S. Sarathi. Lab Evaluation Requires Appropriate Techniques. Four Parts Oil and Gas J., 1986.

6. Engineering Enterprises, Inc. Survey of Class II UIC Programs, Task 1 - Operating, Monitoring, and Reporting. Background Paper. June 1988. Available from EPA, EPA Contract 68-03-3416.

7. Detailed API Study Defines Injection-Well Failure Risks. Oil and Gas J. v. 86, No. 26, June 27, 1988, pp. 46-47.

8. Holm, L. W. Evolution of the Carbon Dioxide Flooding Process. J. of Pet. Tech., Nov. 1987, pp. 1337-1342.

9. EPA Won't Classify Oil Field Wastes as Hazardous. Oil and Gas J., v. 86, No. 28. July 11, 1988, pp. 122.

10. EPA Won't Control Drilling Wastes as Hazardous. Tulsa World, June 30, 1988.

TABLE 1. - Summary of EOR project starts each year by process

	1980	1981	1982	1983	1984	1985	1986	1987
Conventional Steam	19	40	24	18	21	21	22	5
In Situ Combustion	10	4	2	0	0	2	1	0
Unconventional Steam	5	8	3	1	1	1	0	1
Surfactant (Micellar-polymer)	20	3	3	1	1	3	0	0
Polymer	19	34	34	53	54	39	36	5
Alkaline	13	9	0	1	0	0	2	0
Carbon Dioxide Miscible	26	28	10	6	8	11	7	0
Hydrocarbon Gas	2	6	2	8	2	3	1	1
Carbon Dioxide Immiscible	0	1	4	16	11	11	21	0
Nitrogen Gas	3	5	1	1	1	1	0	0
Microbial projects	--	--	--	--	---	---	3	1
Total	117	138	81	104	99	90	93	13

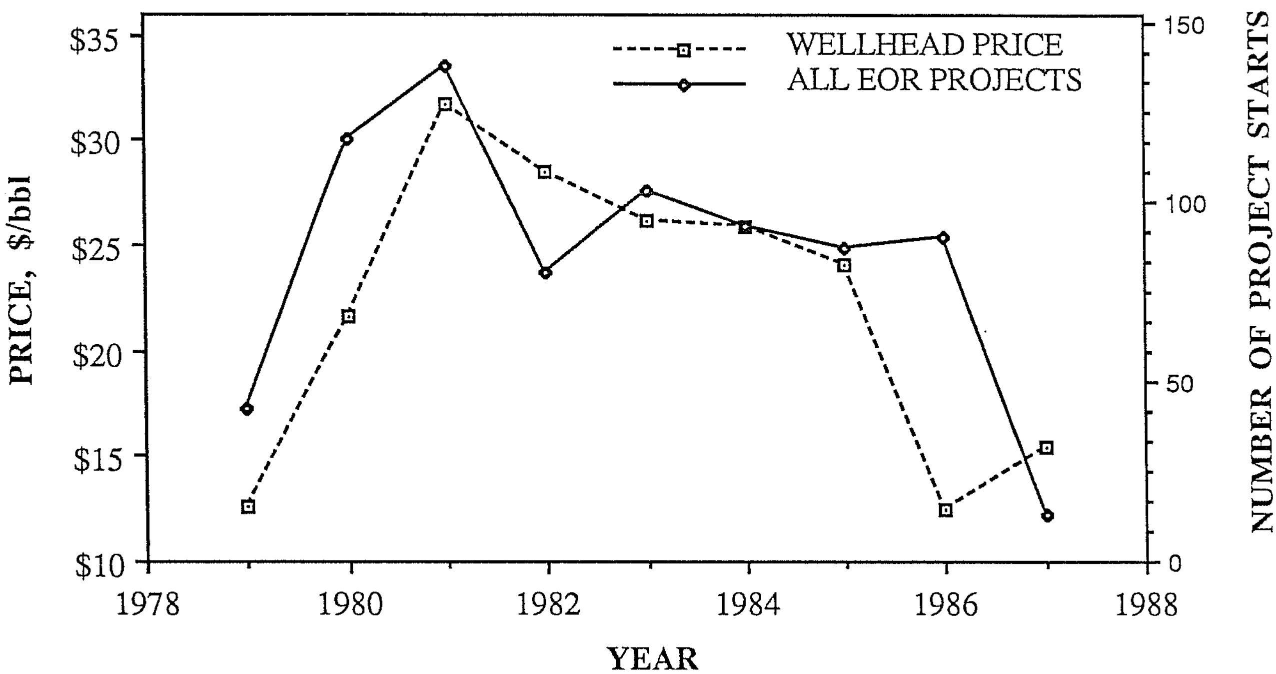

FIGURE 1. - Comparison of wellhead oil price with total EOR project starts between 1979 and 1987.

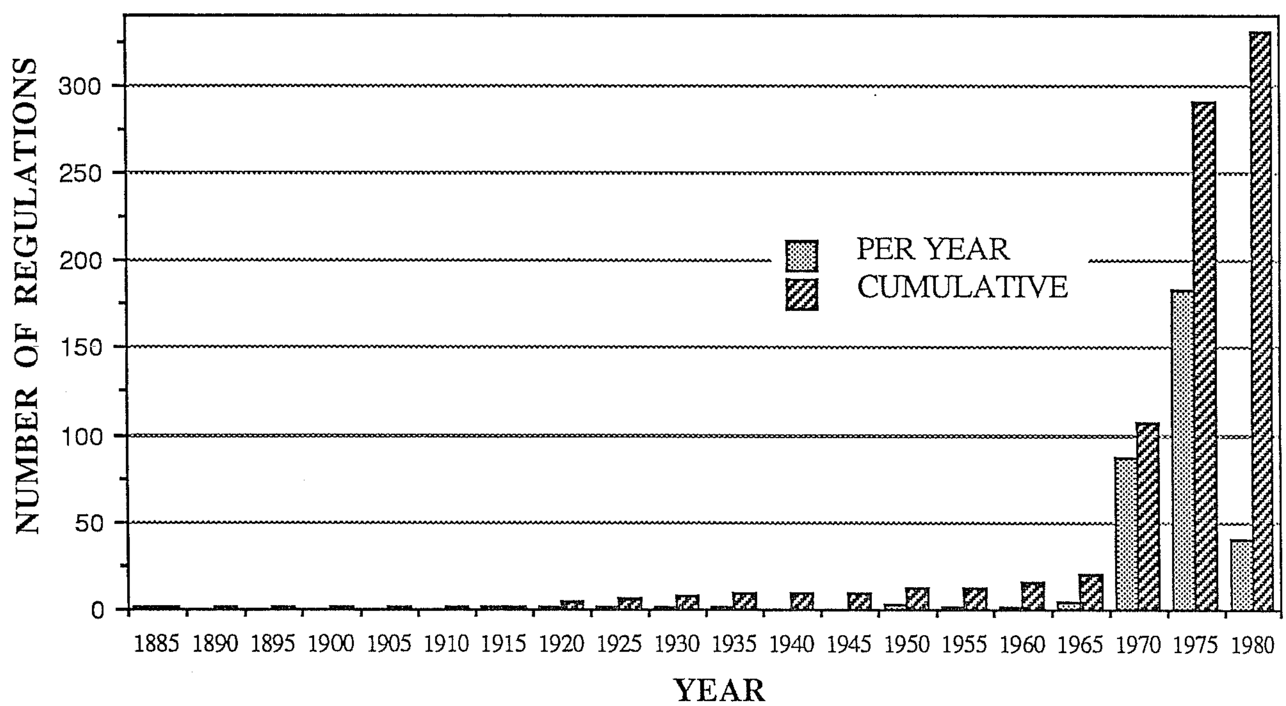

FIGURE 2. - The increasing regulatory burden on the oil and gas industry through 1981 (source: DOE/EIA-0329).

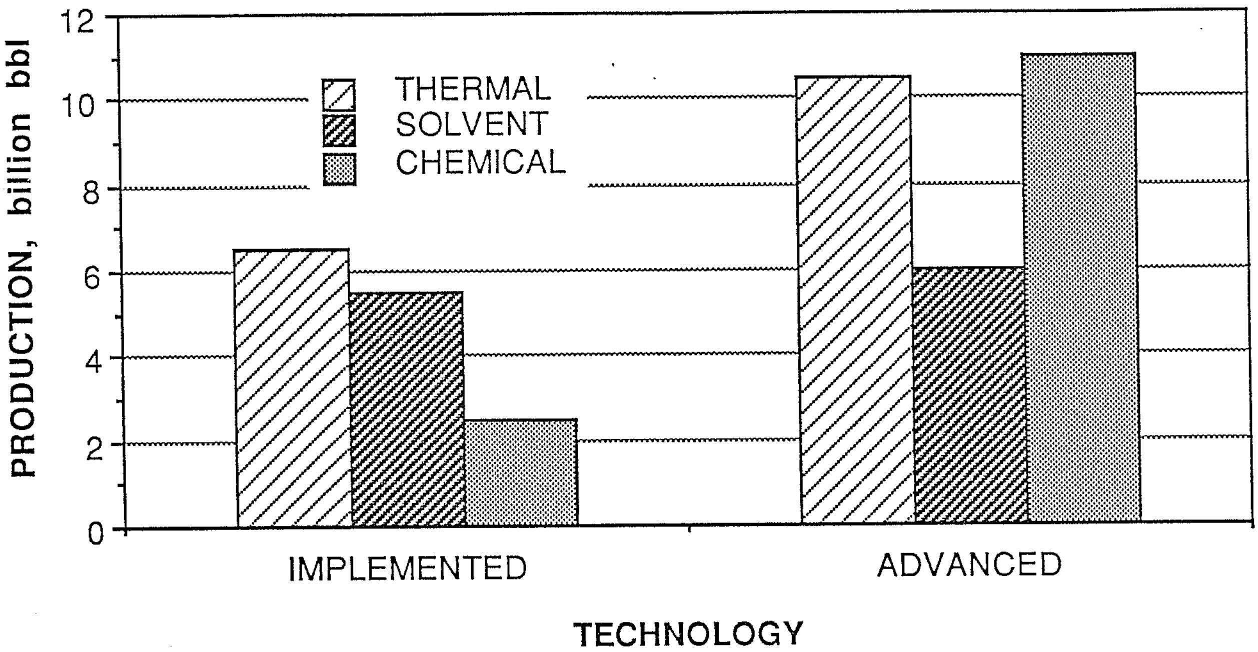

FIGURE 3. - Potential recoveries for specific EOR processes[5] (advanced includes implemented).

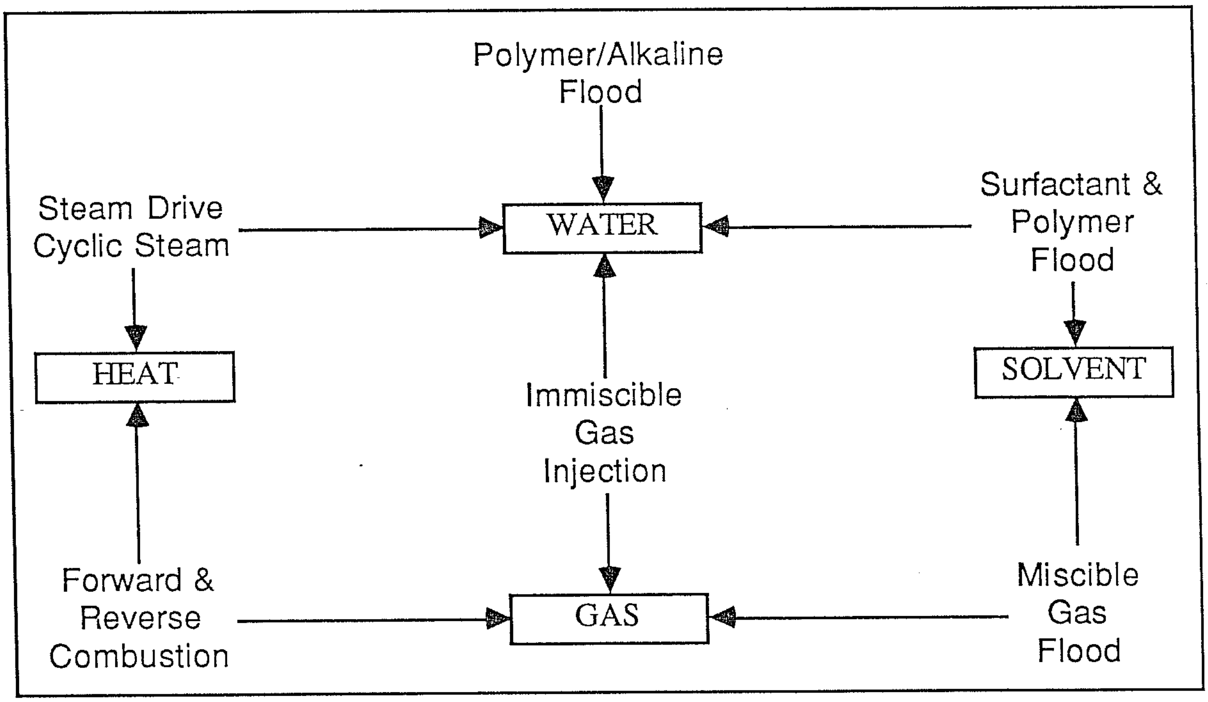

FIGURE 4. - Relationship among specific EOR processes.[5]

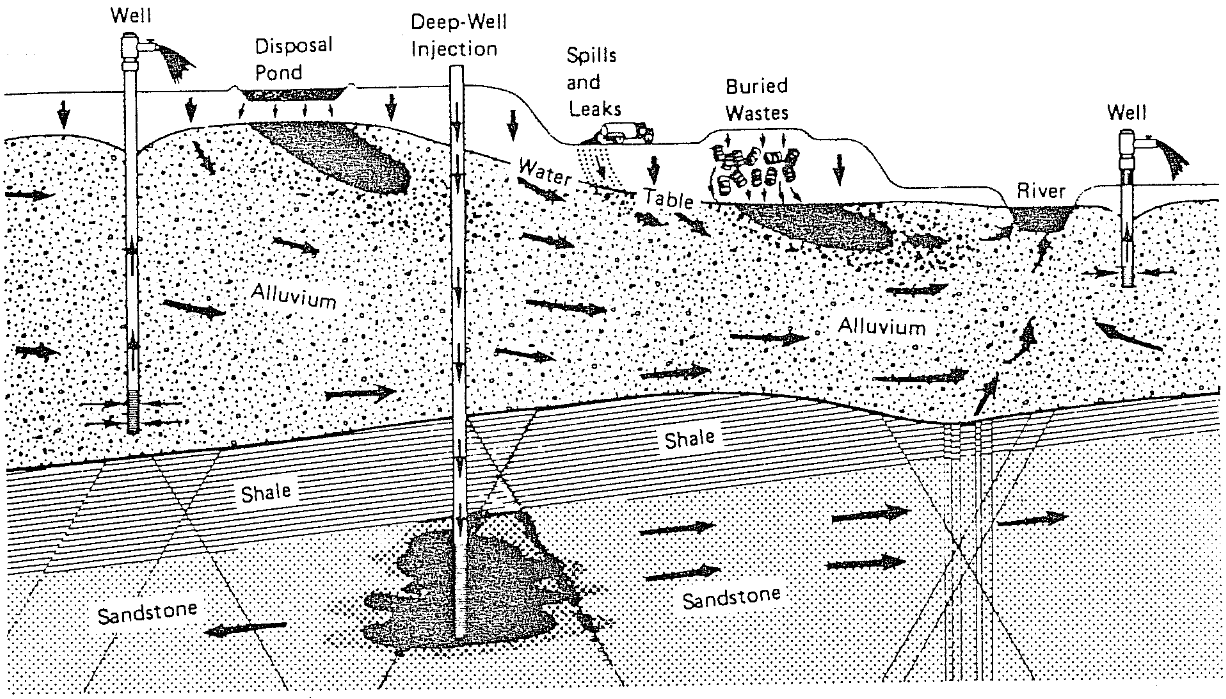

FIGURE 5. - Past methods of waste disposal threaten water supplies today. Reprinted from *Opportunities in Chemistry*, National Academy Press, 1985.